Meta-Analysis of value of travel time savings studies in Switzerland

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本研究ではスイスで行われた研究を主な対象にして, 時間価値のメタ分析を行う. 新規路線を計画する際等の事業効果として, 時間短縮便益は特に大きな割合を占める. したがって, 事業効果分析のために時間価値の推計を行う研究は多く見られる. これらの研究は, 時間価値が移動距離・収入・移動手段など様々な要因に応じて変動することを指摘している. 本研究では, 時間価値に影響を与える要因とその程度について, より包括的な視点から分析を行う為に, メタ分析を採用する. メタ分析とは, 散乱している研究情報を収集し, 質の良いもの悪いものを整理し, それぞれの成果を抽出・整理・統合するための一連のプロセスのことを指す. まず時間価値論文の調査方法, 調査条件, 調査結果を比較可能な形で収集し, 簡単な集計分析を行う. 続いて, 移動距離, 収入, 交通手段などの基本的な要因がどの様に時間価値に影響しているか統計分析により明らかにする.

Key Words : *Value of travel time savings, Meta-analysis, Multi-level model, Switzerland*

1. Introduction

VTTS (Value of Travel Time Savings) represents how much people will pay for the reduction of their travel time. It is a key factor for transport modeling and appraisal as well as prediction of transport demand. Enormous studies have been carried out to estimate VTTS in the past several decades[2) 3) 5)], from which VTTS is known to be affected by not only travel attributes such as mode, purpose and distance, but also socio-economic characteristics and the level of infrastructure development. This complexity is what makes it difficult to estimate the impact of each factor on VTTS. Some studies estimate VTTS by using SP (stated preference) or RP (revealed preference) data based on discrete choice modeling. This approach may be effective to estimate the VTTS for individual survey location. There are other methods to estimate VTTS and to evaluate the impact on variation of VTTS. Meta-analysis, which is widely used in the field of medicine, is one of them. The idea of Meta-analysis is to apply the statistic approach to systematic review by collecting papers related to the certain topic, ordering the result and method in these papers and conducting a statistical analysis. In contrast to descriptive review, it is possible to have a quantitative analysis by this approach. Here we review some literatures about VTTS, which have applied meta-analysis approach. Wardman conducted Meta-analysis of UK values of travel time [1)]. Kato has reported the Meta-analysis of VTTS in Japan [7)]. Shires and de Jong conducted an international meta-analysis of value of travel time savings[4)]. All these papers made use of the Meta-regression model and estimated the impacts of each attribute on VTTS.

In this paper, we present the result of VTTS Meta-analysis using the research papers published by IVT (Institut fur Verkehrsplanung und Transportsysteme) group in Switzerland. Switzerland locates in the center of Europe and the service level of transport infrastructure is quite high, in terms of both public and private transport. What is remarkable in this country is, unlike to other Europe countries, public transport service has high reliability on time similar to Japan.

Two different Meta-regression models are estimated: one is standard multiple linear regression model and the other is multi-level model. Multi-level model is preferable in case data has groups, e.g. panel data or data across different countries. As mentioned later, we extract more than one VTTS data from each paper or each survey result. In that case, it is considered that the estimation results of Meta-analysis would have biases, because of dependence of each VTTS.

The structure of this paper is as follows. Section 2 de-

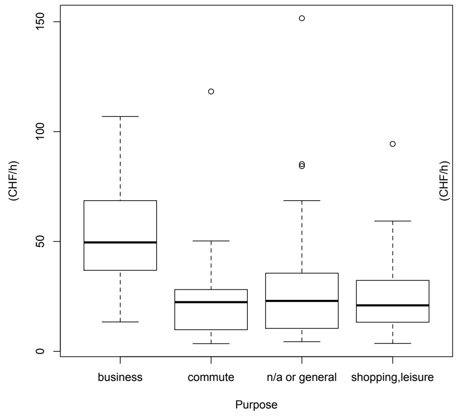

Fig.–1 VTTS variance across purpose

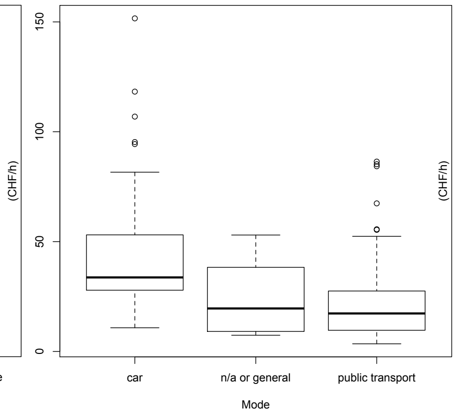

Fig.–2 VTTS variance across mode

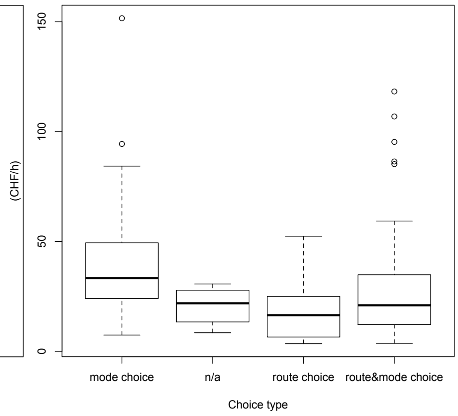

Fig.–3 VTTS variance across choice type

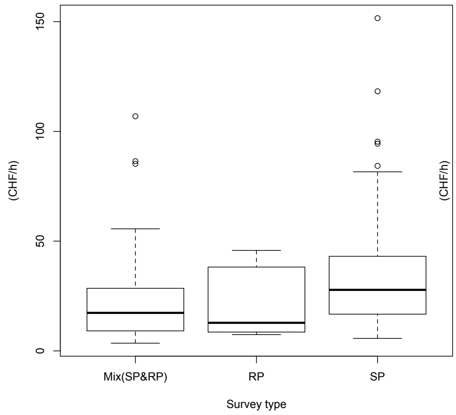

Fig.–4 VTTS variance across survey type

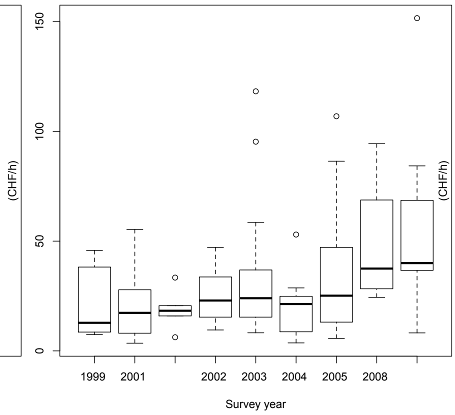

Fig.–5 VTTS variance across survey year

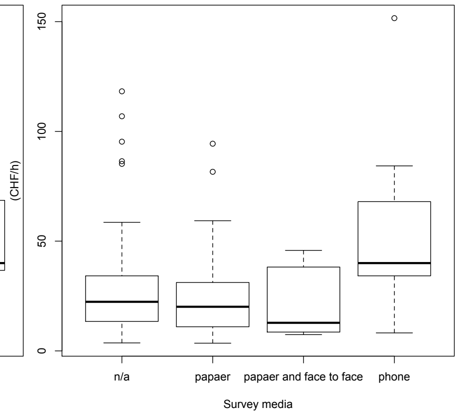

Fig.–6 VTTS variance across survey media

(The average exchange rate in 2011 is approximately 89 Yen/CHF)

scribes how we collect the papers for VTTS Meta-analysis and the variables extracted from these papers. Section 3 contains the result of cross summary, briefly describes the model structure and shows its result. Section 4 covers the empirical findings and discussions.

2. Data

In this section, we describe the dataset used in this paper. First, we choose the papers related to VTTS estimation from IVT database. Secondly, we exclude the paper, which does not include estimated parameters for time and cost. We also exclude the paper, which does not specify the year and location of survey. In this paper, we focus on trip by car and public transportation, instead of trip by airplane and walking. Finally, we remove the highest 2% and the lowest 2% VTTSs, in total 4 samples, as outliers. Surveys in these papers are conducted between 1999 and 2010. We select 131 VTTS estimates from papers in the dataset. The total number of papers is 14. Variable extracted from the papers are as follows.

(a) Information about survey

- Location of survey
- Year of survey
- Survey type: SP, RP or the combination of them
- Number of respondents
- Way of respondent recruitment: internet, phone
- Media for survey: face to face, paper, phone
- Choice type: route choice, mode choice, route and mode choice

(b) Information about model

- Number of parameter
- Log-likelihood
- Number of observation

(c)Variables used in the model

- Transport mode: public transport, train, car
- Purpose: business, commute, leisure, shopping
- Time components: access, congested, free-flow, headway, in vehicle, transfer, travel time, etc.
- Cost components: fuel, parking, ticket fee, toll, travel cost

(d) Information about paper

- Author
- Year of published
- Journal.

Table–1 Result of cross table

	Purpose									
	business		commute		n/a or general		shopping or leisure		Total	
Mode										
n/a or general			0.83	(3)	0.67	(6)	1.07	(3)	0.81	(12)
public transport	1.46	(10)	0.51	(12)	0.82	(30)	0.59	(28)	0.77	(80)
car	2.43	(5)	1.67	(5)	1.33	(16)	1.36	(13)	1.53	(39)
Cost component										
parking, fuel	2.78	(1)	0.83	(1)	0.59	(3)	1.66	(6)	1.39	(11)
ticket fee			1.08	(1)	0.67	(16)	0.72	(6)	0.7	(23)
toll					0.46	(1)			0.46	(1)
travel cost	1.72	(14)	0.83	(18)	1.16	(32)	0.72	(32)	1.03	(96)
Time component										
access time	2.94	(1)	0.8	(1)	1.54	(5)	1.15	(2)	1.52	(9)
congested time	3.24	(1)	4.03	(1)	1.25	(2)	1.99	(1)	2.35	(5)
free flow time	1.47	(1)	0.82	(1)	0.98	(2)	0.89	(2)	1	(6)
headway	0.49	(3)	0.28	(4)	0.32	(7)	0.3	(10)	0.32	(24)
in vehicle time	1.87	(3)	1.01	(4)	0.59	(4)	1.31	(10)	1.19	(21)
transfer time	1.69	(2)	0.19	(2)	0.37	(4)	0.54	(4)	0.62	(12)
travel time	2.17	(4)	0.82	(7)	1.13	(28)	0.88	(15)	1.1	(54)
Total	1.79	(15)	0.85	(20)	0.96	(52)	0.85	(44)	1	(131)
	business		commute		n/a or general		shopping,leisure		Total	
Survey type										
Combined(SP & RP)	1.98	(7)	0.46	(8)	0.73	(24)	0.62	(16)	0.81	(55)
RP			0.83	(3)	0.35	(4)	1.07	(3)	0.71	(10)
SP	1.62	(8)	1.2	(9)	1.29	(24)	0.98	(25)	1.2	(66)
Travel distance										
urban			0.83	(3)	0.9	(15)	0.9	(11)	0.89	(29)
inter city	1.79	(15)	0.85	(17)	0.98	(37)	0.83	(33)	1.03	(102)
Choice type										
mode choice	2.78	(1)	0.88	(5)	1.37	(19)	1.54	(7)	1.37	(32)
n/a	0.75	(2)	0.49	(2)			0.76	(5)	0.7	(9)
route choice	1.64	(2)	0.26	(3)	0.69	(7)	0.43	(6)	0.64	(18)
route & mode choice	1.93	(10)	1.07	(10)	0.73	(26)	0.78	(26)	0.96	(72)
Model type										
Mixed logit model			0.83	(3)	0.26	(2)	0.79	(7)	0.71	(12)
Multinominal logit model	2.08	(8)	0.56	(10)	0.99	(50)	0.91	(24)	1.01	(92)
n/a	1.06	(3)	0.9	(3)			0.72	(6)	0.85	(12)
Others	1.75	(4)	1.54	(4)			0.83	(7)	1.26	(15)
Survey media										
n/a	1.95	(9)	1	(9)	0.83	(28)	0.77	(17)	1	(63)
papaer	1.54	(6)	0.67	(8)	0.51	(9)	0.88	(24)	0.86	(47)
papaer and face to face			0.83	(3)	0.35	(4)	1.07	(3)	0.71	(10)
phone					1.87	(11)			1.87	(11)
Total	1.79	(15)	0.85	(20)	0.96	(52)	0.85	(44)	1	(131)

value represents the ratio between VTTS for that cell and the average VTTS
value in the parenthesis is number of samples

3. Results

(1) Summary Statistics of VTTS

At first, we summarize the statistics of VTTS values obtained from the papers by each different categories, the part of which are shown in Figures 1 to 6. The sample average of all VTTS is 29.4 CHF/hour, which is approximately equivalent to 2,617 YEN/hour in Japanese currency.

(2) Cross Table Analysis

Table 1 shows the result of cross table analysis, which has transport purpose in row and other variables in column. The value in each cell represents the ratio between VTTS in that cell and the average of all VTTS samples. With regard to Purpose, VTTS for business trip is generally over twice more than those for leisure, shopping and commute. Such a tendency does not change in any combination in the table, except the one with congested time in time component. Compared to public transport, car users has higher VTTSs, which is similar to Japanese case but differs from UK case. The difference might come from the service level of public transport. When it comes to cost component, VTTS obtained from ticket fee and toll is comparatively low. It means that people do not like to pay much money for ticket fee and toll, compared with parking fee or fuel. This consideration comes from the fact that VTTS is calculated as parameter for time divided by parameter for cost. Hence in case SP survey is conducted, it should be take into account that the cost type may have impact on the VTTS. Time component could be considered similar way, but opposite direction. Higher VTTS value means objection to

Table–2 Variables used in the model

Purpose dummies	
Purpose.commute	Dummy variable that takes the value of 1 if VTTS for commuting; otherwise 0. (base = business)
Purpose.n.a or general	Dummy variable that takes the value of 1 if VTTS for general or n/a purpose; otherwise 0. (base = business)
Purpose.shopping,leisure	Dummy variable that takes the value of 1 if VTTS for shopping and/or; otherwise 0. (base = business)
Mode dummies	
Mode.n/a or general	Dummy variable that takes the value of 1 if VTTS for general or n/a mode; otherwise 0. (base = car)
Mode.public transport	Dummy variable that takes the value of 1 if VTTS for public transport; otherwise 0. (base = car)
Time component dummies	
Time_comp.congested	Dummy variable that takes the value of 1 if VTTS for congested time; otherwise 0. (base = access time)
Time_comp.free flow	Dummy variable that takes the value of 1 if VTTS for free flow time; otherwise 0. (base = access time)
Time_comp.headway	Dummy variable that takes the value of 1 if VTTS for headway; otherwise 0. (base = access time)
Time_comp.in vehicle	Dummy variable that takes the value of 1 if VTTS for in vehicle time; otherwise 0. (base = access time)
Time_comp.transfer	Dummy variable that takes the value of 1 if VTTS for transfer time; otherwise 0. (base = access time)
Time_comp.travel	Dummy variable that takes the value of 1 if VTTS for travel time; otherwise 0. (base = access time)
Survey media dummies	
Survey_media.papaer	Dummy variable that takes the value of 1 if VTTS from survey conducted by paper questionnaire; otherwise 0. (base = n/a)
Survey_media.papaer and face to face	Dummy variable that takes the value of 1 if VTTS from survey conducted by paper and face to face; otherwise 0. (base = n/a)
Survey_media.phone	Dummy variable that takes the value of 1 if VTTS from survey conducted by phone interview; otherwise 0. (base = n/a)
Survey type dummies	
Survey_type.SP	Dummy variable that takes the value of 1 if VTTS from SP data; otherwise 0. (base = RP or combination of SP & RP)
Economic variable	
GDP_per_capita	Numerical variable for GDP per capita in survey year(in 1,000 CHF)

increase of relevant time. In this case, people will avoid increasing access time or congested time, rather than headway or free flow time. Respect to survey type, SP survey data has higher VTTS than RP survey. This is similar to the result in UK case, but different from Japanese case. In general, SP survey has higher VTTS, because people do not have to pay in real life and state higher willingness to pay for reduction of travel time. VTTS in mode choice situation shows value almost twice as that of route choice. This suggests a possibility that people more cares about travel time when they decide trip mode. Survey media also seems to affect to the survey result. VTTS from survey by phone interview shows higher value.

In general, survey by face to face or phone has reliability, compared to survey via internet or paper, because they are likely to spare longer time. But in relatively unreliable survey, we cannot confirm if the VTTS is higher or lower than the true value.

(3) Meta-regression model

OLS model

We conduct two different model estimations. First is the model for multiple regression analysis by OLS (Ordinary Least Squares), which is commonly used in the meta analysis of VTTS (See Wardman 1998[6)]). Variables used in the model are shown in Table 2, and the model specification is as follows.

$$ln(VTTS_i) = \mu + \alpha lnGDP_i + \sum_{j=1}^{p} \beta_j Z_{ij} + u_i \qquad (1)$$

where, $VTTS_i$: i (=1, ..., n)th VTTS, μ: constant term, GDP_i : GDP per capita in 1000 CHF associated with ith VTTS, Z_{ij}: dummy variable which returns 1 if the ith VTTS has j(=1, ..., p)th variable, u_i: error term following standard normal with N(0, σ^2), α, β_j: unknown parameters.

Multi-level model

Survey data often has groups or clusters. Assume that we have panel data for score in high school exam for several years, which includes score, learning time, and so on. Perhaps the data would have bias according to each individual or each school. In such cases, we should be careful to apply normal regression analysis, because normal regression model has the assumption of independence of each sample. Multi-level model is useful to be applied to these data, which have some similarities within the same groups or clusters. The data used in this paper may have bias, because we extract more than one samples from each survey data. For this reason, we also apply Multi-level model for model estimation.

There are three variants of Multi-level model. First is the model which has random effect in constant term. Second is the model which allows random effect in coefficients of variables. Third is the model which allows random effect in both constant term and coefficients of variables. In this paper, we only apply the first model, which includes random effect in constant term. Within this model, the constant term is estimated for each group of survey data sources. Eq.2 shows the structure of the model. Basic structure is similar to the OLS model in eq.1. The difference is that the constant term μ_k is estimated for each survey data source group $k(= 1, ..., m)$.

$$ln(VTTS_i) = \mu_k + \alpha lnGDP_i + \sum_{j=1}^{p} \beta_j Z_{ij} + u_i \qquad (2)$$

$$where\ \mu_k = \mu_0 + u_k \qquad (3)$$

μ_0: average constant term for all samples
u_k: error term for each group.

Table 3 shows the estimation result of two model. In general, the impact of variables on VTTS shows similar characteristics as the cross summary in Section 3.(2). At first, we have considerations on the result of OLS model. With regard to coefficients for purpose, commute, leisure or shopping, and general or n.a. have negative impact, compared to business(=base), and all of them are statistically significant. The coefficient for public transport shows negative value, compared to that of car(=base), and it is significant. The coefficient for general or n/a mode has the value between them. When you see the time component oriented coefficients, you find congested time and access time(=base) have positive effect on VTTS, compared to free flow time, headway and in vehicle time. It is consistent with our intuition, it is natural, because increase of congested time or access time contribute to a feeling of discomfort, and the degree of it is higher than free flow time. What is remarkable here is that coefficient headway has quite low value. This result suggests that people do not care much about increase of headway, because it does not necessarily contribute to increase of their travel time. With regard to survey type, coefficient of SP data has higher than that of RP or combination of SP&RP, but the statistic significance of it is not so high. It shows that the effect of difference between SP and RP data is not absorbed by other factors, and has some impact on VTTS. GDP per capita in survey year seems to have positive impact, suggesting that the VTTS increases, as the GDP per capita increases.

Comparing the model estimates in Multi level model with that of the OLS model, no large difference in the value of coefficients and t value are found, except for the parameters for constant term and GDP per capita. The difference of constant term reflects the variance between each survey data source. The difference between the average constant term and the specific constant term for each survey data source are shown in downside of the table. Part of these differences might come from factors not described in the model, such as region-specific factor, travel distance or income. According to the fact that the Multi level model has lower coefficient for GDP, part of the variance between each survey data source could be explained by GDP in OLS model.

In addition, we estimated the Multi level model which has random effect in both coefficients for purpose oriented variable and constant term. However, the estimated result is rarely different from the model with random effect only in constant term. This paper focuses on the Swiss VTTS, and the variance across survey data sources would be lower than international VTTS.

4. Conclusion

In this paper, we conduct the Meta-analysis of value of travel time savings, by using 131 VTTS samples from the 14 literatures published in Switzerland. Through the cross table analysis and the meta-regression analysis, some features are obtained. As for meta-regression model, we apply two different models: the commonly used regression model (OLS) and the Multi-level model. The motivation for Multi level model is to avoid the bias of multi sampling from each survey data. Our findings in this paper are as follows.

- The sample average of all VTTS is 29.4 CHF/hour (2,617 YEN/hour).
- Business trip has larger VTTS, generally twice more than other purpose's.
- GDP per capita has positive impact on VTTS.
- In terms of time component, VTTS for congested time and access time seem to be high.
- VTTS obtained from SP data is relatively higher than the one obtained from combined of RP and SP data.
- The constant term for each survey data are estimated with the Multi level model estimates . In most variables, the coefficients of constant effect do not change much.

Meta-analysis is useful to evaluate the general tendency, which cannot be obtained from individual researches. But there are some difficulties with this method. For example, income and trip distance have considerable impact on VTTS, but it is difficult to include in Meta-analysis model. Generally the raw data used in literatures is not available, while we can get the results from the data. Our future work is to build in these variables into meta-regression model, by using variables which is available from literatures.

Table–3 Estimation results of Meta-Regression Analysis

	OLS estimates			Multi level model		
	coefficient	t value		coefficient	t value	
(Intercept)	2.85E-01	0.139		4.91E-01	0.174	
Purpose.commute	-8.44E-01	-4.764	***	-7.58E-01	-4.186	***
Purpose.n.a or general	-9.81E-01	-6.239	***	-9.01E-01	-5.314	***
Purpose.shopping,leisure	-7.35E-01	-4.739	***	-6.64E-01	-4.137	***
Mode.n/a or general	-2.80E-01	-0.624		-3.15E-01	-0.603	
Mode.public transport	-3.20E-01	-2.35	*	-3.31E-01	-2.413	*
Time_comp.congested	9.22E-02	0.266		6.63E-02	0.187	
Time_comp.free flow	-6.59E-01	-1.973	.	-6.88E-01	-2.011	*
Time_comp.headway	-1.33E+00	-6.15	***	-1.35E+00	-6.355	***
Time_comp.in vehicle	-4.12E-01	-1.562		-4.50E-01	-1.713	.
Time_comp.transfer	-8.76E-01	-3.687	***	-8.66E-01	-3.706	***
Time_comp.travel	-3.81E-01	-1.842	.	-4.02E-01	-1.973	*
Survey_media.papaer	-2.72E-01	-1.903	.	-2.05E-01	-1.22	
Survey_media.papaer and face to face	-9.12E-02	-0.192		-6.15E-02	-0.11	
Survey_media.phone	2.27E-01	0.875		2.64E-01	0.758	
Survey_type.SP	2.09E-01	1.571		2.01E-01	1.082	
GDP_per_capita	7.03E-02	2.133	*	6.59E-05	1.446	
random effect						
ICN				-1.05E-02		
Joint(ICN,Kanton, Mobiprc,SV)				-1.09E-01		
KEP 2001				-4.51E-02		
KEP 2003				3.87E-02		
KEP 2008				6.63E-02		
KEP2010				-8.54E-16		
KITE 2004				-2.76E-16		
Kanton Zurich				-1.25E-01		
Koenig 2001				2.09E-02		
Mobidrive data				-4.15E-16		
Mobility pricing				1.59E-01		
SBB 2005				-1.26E-01		
SV data				1.30E-01		
Sample size	131			131		
Number of parameters	18			31		
AIC	214			266		
Final logliklihood	-89.16			-114.1		
Adj. R-squared	0.6					

.: 10%, *: 5%, **: 1%, ***: 0.1% significant

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Appendix

Literatures used in the Meta-analysis

No	Title	Authors	Publication	published year
1	Models of mode choice and mobility tool ownership beyond 2008 fuel prices	Weis, C., K.W. Axhausen, R. Schlich and R. Zbinden	Transportation Research Board of the National Academies	2010
2	Reducing bias in value of time estimates by joint estimation on multiple datasets	Hess, S., A. Erath and K.W. Axhausen	European Transport Conference 2007	2007
3	Estimated value of savings in travel time in Switzerland	Hess, S., A. Erath and K.W. Axhausen	Transportation Research Board of the National Academies	2008
4	Mode choice of complex tours: A panel analysis	C. Cirillo, K.W. Axhausen	Arbeitsbericht Verkehrs- und Raumplanung 142	2002
5	Mode choice of complex tours	C. Cirillo, K.W. Axhausen	European Transport Conference	2001
6	Evidence on the distribution of values of travel time savings from a six-week diary	C. Cirillo, K.W. Axhausen	Transportation Research Part A	2006
7	Estimation of the Swiss Valuation of Travel Time Savings	Hess, S.	Arbeitsbericht Verkehrs- und Raumplanung,, 381	2006
8	Income and distance elasticities of values of travel time savings	Axhausen, K.W., S. Hess, A. Koenig, G. Abay, J.J. Bates and M. Bierlaire	Transport Policy	2008
9	The impact of tilting trains in Switzerland: a route choice model of regional- and long distance public transport trips	M Vrtic, K.W. Axhausen	Annual Meeting of the Transportation Research Board	2002
10	Route, mode and departure time choice behaviour in the presence of mobility pricing	Vrtic, M., N. Schussler, A. Erath and K.W. Axhausen	Transportation Research Board	2007
11	Influence of Parking on Location and Mode Choice	Weis, C., M. Vrtic, P. Widmer and K.W. Axhausen	Arbeitsberichte Verkehrs- und Raumplanung	2011
12	Choosing carpooling or carsharing as a mode: Swiss stated choice experiments	Francesco CIARI, Kay W. Axhausen	Transportation Research Board	2012
13	Time is money - The valuation of travel time savings in Switzerland	Arnd Koenig, K.W. Axhausen	Swiss Transport Research Conference	2003
14	Report about results: user requirements and indications about demand volumes	Andreas Frei, K.W. Axhausen	KITE - a knowledge base for intermodal passenger travel in Europe	2009